

Barometric Compensation Assistant:

This white paper presents application and technical details for the Barometric Compensation Assistant (BCA), a Post-Processor designed for use with HOBOWare Pro on the PC or Mac.

Post-Processors Overview

All available Post-Processors exist in the Processors directory in the HOBOWare Pro installation. All available Post-Processors are accessible from the Plot Setup Dialog in HOBOWare. Each has a set of dependencies; channel-types it needs to become available when a particular dataset is displayed in the Plot Setup Dialog. A user can select a Post-Processor from the list and click the Process button, allowing them to progress through the logic contained in the Post-Processor. Upon completion of a Post-Processor, one or more new channels are added to the list of available channels to plot.

Application Details

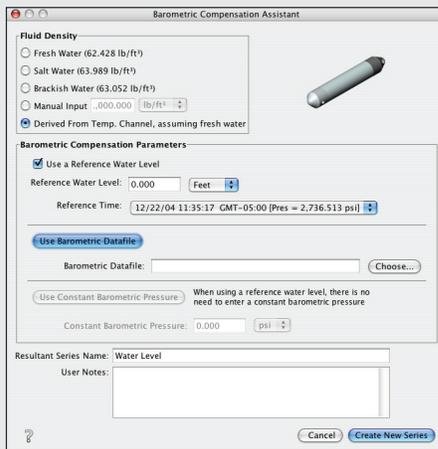
This section includes details on how the user would be expected to prepare data for use with the Barometric Compensation Assistant. The BCA supports all HOBO U20 Water Level Loggers. The details of how to use the assistant are left to the HOBOWare Manual. Included here is the definition of how depth will be determined from pressure readings, how the water density will be factored into that computation, and how that density will be temperature-compensated.

The following HOBO data loggers can be used to provide the barometric data file.

- HOBO U20 Water Level Logger (0-13 ft and 0-30 ft models)
- HOBO Weather Station & Micro Station with Pressure Sensor attached
- HOBO Energy Logger Pro with Pressure Sensor attached
- HOBO U30 with Pressure Sensor attached

User Interface

This dialog associated with the BCA allows information about the barometric data, time, reference water depth, and water density to be gathered and used in the calculation of the new “Water Level” or “Sensor Depth” channel. Components of the dialog are shown and described below. More detail can be found in the HOBOWare manual.



Fluid Density Panel

This panel allows the user to input the density of the fluid in which the logger was deployed. Four choices are provided: Fresh Water, Brackish Water, Salt Water, Manual Input, and Derived from Temperature Channel. If Manual Input is selected, the Water Density text field and associated units combo box will be enabled. This control will be generally initialized to Fresh Water. As with all controls in the BCA, it initializes to the last value used. If temperature was not logged, the “Derived From...” radio button will be disabled.

Water Density Text Field

This control is disabled unless the Manual Input element of the Specific Gravity ComboBox is selected. Once enabled, it will be configured to accept only positive floating-point values. The last value entered in this field will be saved as a hidden preference and displayed the next time the dialog is rendered.

Use A Reference Water Level Checkbox

Indicates whether the user has a manually measured reference water level. This measurement is necessary to maximize accuracy.

Reference Water Level Text Field

The user selects the manual depth or height measurement in this box. Negative values indicate the distance below a fixed reference point, generally a well cap. Positive values indicate the water height above a reference point, generally sea level. An associated Combo Box determines the units.

Reference Time Combo Box

This allows the user to pick the Reference Water Level time of measurement from the list of times in the downwell pressure channel.

Use Barometric Datafile Button and Text Field

The Choose button associated with these controls launches a file chooser with a datafile filter. Once the file is chosen, the dataset contained in the file will be checked to determine if it has a pressure channel that can be used for compensation. If no pressure channel is found, the user is asked to pick another file until a file with a proper pressure channel is found. Once the file has been selected, the pathname is displayed in the text field.

Use Constant Barometric Pressure Button and Text Field

This button enables the user to input a constant barometric pressure and specify its units.

Create New Series Button

Pressing this button causes the BCA to gather all user-data from the user interface and generate the new Water Level or Sensor Depth channel.

Cancel Button

Pressing this button causes the dialog to be dismissed.

Technical Details

This section presents the details of how the Pressure values are computed, and how Pressure and Temperature values are converted to Water Level or Sensor Depth depending on the information supplied by the user. Where relevant to the discussion, equations are included.

Glossary of Terms

T_{raw}	Raw 12-bit Temperature value from logger
T_{real}	Temperature value after being run through the transfer function
T_{ref}	Temperature value at the reference time
P_{raw}	Raw 14-bit Pressure value from logger
P_{real}	Pressure value after being run through the transfer function, which is a function of raw pressure and raw temperature.
P_{baro}	Barometric pressure at the reference time selected by user
P_{const}	Constant value for barometric pressure
P_{hyd}	Hydraulic Pressure
D_{ref}	Calculated reference water depth at the reference time, extracted from the downwell pressure data
D_{baro0}	Calculated barometric "depth" at the reference time, extracted from the barometric pressure data
$D_{real}[]$	An array of actual computed sensor depth values
L_{meas}	Manually measured reference water level from a fixed reference, such as a well cap or sea level.
$L_{real}[]$	An array of actual computed water level values
ρ	Density
ρ_{ref}	Density of fluid at time of reference
k	Barometric compensation constant

Pressure Calculation

Barometric compensation is performed by a set of Java classes that encapsulate the process of performing the conversion of pressure values to true depth readings. Before performing barometric compensation, the raw values from the logger must be converted into real pressure. HOBOWare's communications interface is responsible for extracting the raw A/D pressure and temperature data (raw counts) from the logger and performing the initial processing into real pressure and temperature, as follows.

1. Extract raw 12-bit Temperature values (T_{raw}) from logger.
2. Extract raw 14-bit Pressure values (P_{raw}) from logger.
3. Extract transfer function/calibration constants ($K_n \dots K_2, K_1, K_0$ and $J_n \dots J_2, J_1, J_0$) from the EEPROM inside the logger.
4. Apply transfer function to the T_{raw} data to generate T_{real} *
5. Apply transfer function to the P_{raw} data to generate P_{real} *

6. Store T_{real} and P_{real} values in separate channels in the resultant dataset.

The resultant dataset is then passed to the HOBOWare user interface for post-processing in the BCA. This post-processing is described next.

Water Level / Sensor Depth Calculation

There are several options for computing water level or sensor depth that can be grouped into two categories, using or not using a reference water level. The recommended method is to use a measured reference water level, therefore it is presented first.

Using a Reference Water Level

Note that this option results in the calculation of a Water Level relative to a fixed reference point, not a Fluid Depth.

First, a temperature and density corrected depth array is computed. This is the depth assuming all pressure is from hydraulic head (no air pressure).

To compute this array, first the fluid density is computed. This is either determined by the user-selected density, or is computed from the temperature at the reference time, via:

$$\rho = (999.83952 + 16.945176 T_{ref} - 7.9870401e-03 T_{ref}^2 - 46.170461e-06 T_{ref}^3 + 105.56302e-09 T_{ref}^4 - 280.54253e-12 T_{ref}^5) / (1 + 16.879850e-03 T_{ref}) \quad [1]$$

Density is converted to lb/ft³ via:

$$\rho = 0.0624279606 p \quad [2]$$

The array of downwell pressure values, P , are then converted to a density dependent fluid depth array, $D[]$, via:

$$D[] = \text{FEET_TO_METERS} * (\text{KPA_TO_PSI} * \text{PSI_TO_PSF} * P) / \rho \quad [3]$$

Where,

$$\begin{aligned} \text{FEET_TO_METERS} &= 0.3048 \\ \text{KPA_TO_PSI} &= 0.1450377 \\ \text{PSI_TO_PSF} &= 144.0 \end{aligned}$$

The density dependent depth value at the reference time is then extracted from the array:

$$D_{ref} = D[\text{Ref Time}]$$

The remaining steps to compute water level values can be done in one of three ways, as follows.

Using a Barometric Datafile

If the user chooses to compensate with a barometric datafile, the following steps are taken.

The Pressure value in the barometric dataset closest to the selected referencetimeisdetermined.Ifthereisnotatimeinthebarometricpressure channel that coincides with the reference time, a value is determined via linear interpolation. This reference pressure is referred to as P_{baro0} *

Next, the fluid density at the reference time is determined. This is either the user-entered density, or is computed from Equations 1 & 2, resulting in ρ_{ref} .

The pressure at the reference time is converted to a barometric “depth” using Equation 3, resulting in D_{baro} .

The compensation constant, k , is determined by:

$$k = L_{meas} - (D_{ref} - D_{baro}) \quad [4]$$

At this point, the compensation constant is applied to each downwell barometric depth reading in the array, D . An important step here is to determine the proper barometric pressure value to use. Since the BCA does not require that the barometric pressure channel have the same sample times as the downwell pressure channel, individual values for barometric pressure, P_{baro} , may sometimes be interpolated between the points closest to the downwell pressure value of interest.

Loop through the entire downwell channel, applying the compensation constant to the density dependent fluid depth values computed above. This is the step that adjusts the density dependent depth values for fluctuations in barometric pressure. This is determined by:

$$L_{real}[] = D[] - D_{baro}[] + k \quad [5]$$

Where $L_{real}[]$ is an array of the actual water level values (from a fixed reference point), D is the density dependent fluid depth array computed earlier, D_{baro} is the barometric depth at the time index in the array (using Equation 3), and k is the compensation constant. The values of L_{real} are stored in a new Water Level channel and added to the list of available channels to plot.

Using No Barometric Data

If the user chooses not to use a barometric datafile, the process of generating a water level is simple, although less accurate. The resultant water level values in this case do not take into account fluctuations in barometric pressure. In this case, the compensation constant is defined as:

$$k = L_{meas} - D_{ref} \quad [4]$$

Loop through the entire downwell channel, applying the compensation constant to the density dependent fluid depth values computed above. The array of actual water level values is computed using:

$$L_{real}[] = D[] + k \quad [5]$$

The values of L_{real} are stored in a new Water Level channel and added to the list of available channels to plot.

Using a Constant Barometric Pressure

The equations used to generate water level using a reference water level and a constant barometric pressure result in the constant pressure term falling out. Since the constant barometric pressure value does not affect the resulting water level, this option is intentionally disabled in the BCA.

Not Using a Reference Water Level

If no reference water level data is available, the only option is to compute sensor depth below the water surface. This can be done using a barometric datafile or a constant barometric pressure value supplied by the user. Using a barometric datafile is the more accurate of the two methods and is presented first.

Using a Barometric Datafile

Loop through the entire downwell data array. First, generate the fluid density, ρ , for each time in the array. This is either determined by the user-selected density, or is computed from the temperature at the reference time, using Equations 1 & 2.

Next, compute the hydraulic pressure at each time, $P_{hyd}[]$, using:

$$P_{hyd}[t] = P_{real}[t] - P_{baro}[t] \quad [6]$$

Where $P_{real}[]$ is the array of measured downwell pressure values and $P_{baro}[]$ is the array of measured barometric pressure values.

Finally, convert the hydraulic pressure to sensor depth, D_{real} , using Equation 3. The values of D_{real} are stored in a new Sensor Depth channel and added to the list of available channels to plot.

Using a Constant Barometric Pressure

The first step is to grab the value of constant barometric pressure, P_{const} , and convert to kPa if necessary.

Next, loop through the entire downwell data array. First generate the fluid density, ρ , for each time in the array. This is either determined by the user-selected density, or is computed from the temperature at the reference time, using Equations 1 & 2.

Next, compute the hydraulic pressure at each time, $P_{hyd}[]$, using:

$$P_{hyd}[t] = P_{real}[t] - P_{const} \quad [7]$$

Where $P_{real}[]$ is the array of measured downwell pressure.

Finally, convert the hydraulic pressure to sensor depth, D_{real} , using Equation 3. The values of D_{real} are stored in a new Sensor Depth channel and added to the list of available channels to plot.

About Onset

Onset Computer Corporation has been producing small, inexpensive, battery-powered HOBO data loggers since 1981, and has sold over 1,000,000 loggers that are used throughout the world by over 50,000 customers. The company manufactures a broad range of data logger <http://www.onsetcomp.com/data-logger> and weather station products that are used to measure temperature, humidity, light intensity, voltage, and a broad range of other parameters. Onset data loggers are used in a wide range of research, commercial, industrial, and renewable energy applications.

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